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ABSTRACT

The Ohio Off-Grade Proficiency Tests help in monitoring students' progress toward Ohio's adapted model courses of study in reading, mathematics, citizenship, science, and writing. The purpose of this study was to provide item response theory (IRT) parameter estimates and descriptive statistics of the scoring categories of the short-response items (SRI) and extended response items (ERI) of the Ohio Off-Grade Proficiency Test-Mathematics. It also aims to provide information about the interactive roles of Ability, Type of Item Response, Gender, and Race, in student performance by using both multiple-choice and partial credit scores in determining student ability levels. Fifth-graders (n=4830) from a large urban area in northeast Ohio participated in the study. Results indicate that Gender did not play a significant role whereas with regard to factor Race, there were significant differences in student scores. Contains 19 references. (ASK)

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Partial Credit Analysis of Mathematics Items from the Ohio-Off Grade Proficiency Tests

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Partial Credit Analysis of Mathematics Items from the Ohio Off-Grade Proficiency Tests

The Ohio Off-Grade Proficiency Tests (OOPT) help in monitoring students' progress toward Ohio's adopted model courses of study in reading, mathematics, citizenship, science, and writing. They include multiple-choice, short response, and extended response items (Riverside Publishing, 1997). While provided with a variety of descriptive reports, Ohio's educational researchers and decision makers do not have information regarding the role the type of item response and factors such as gender, race, and ability level in the OOPT performance of local student populations. Such information can help in making decisions about improving students' achievement in urban schools populated by minority children, where the achievement problems were seen as being worse (see, e.g., the "Nation at risk" report of the National Commission on Excellence in Education, 1983).

Previous studies have investigated differences in mathematics achievement as they relate to single factors such as gender and race, without providing information about their interaction with different types of item response and/or students' ability level (e.g., Friedman, 1989, 1995; Benbow & Stanley, 1980; Dossey, Mullis, Lindquist, & Chambers, 1988; Lewis & Hoover, 1986; Cooper & Dorr, 1995; Graham, 1995; Losey, 1995; King, 1993). A recent study (DeMars, 1998) invesitgated the role of gender, respose format, and abillity in mathematics and science high schol proficiency exam, but (a) it did not take into account the factor Race, and (b) it used the multiple-choice total score to determine student ability, i.e., it did not take into account the partial credit scores of the students in determining their ability scores.

Purpose of the study

The purpose of this study is twofold. *First*, it is to provide IRT parameter estimates and

descriptive statistics of the scoring categories of the short-response items (SRI) and extended response items (ERI) of the Ohio Off-Grade Proficiency Test-Mathematics (OOPT-M). *Second*, by using both multiple-choice and partial credit scores in determining student's ability level, to provide information about the interactive role of Ability, Type of Item Response, Gender, and Race, in students' performance on the OOPT-M.

Method

Instrument

Used in this study were results from the OOPT-M for grade five (Riverside Publishing, 1995). It includes 30 multiple-choice items (MCI), 8 short response items (SRI), and 2 extended response items (ERI). A dichotomous scale (0, 1) is used for the MCI, a partial credit scale (0, 1, 2) , for the SRI, and a partial credit scale (0, 1, 2, 3, 4), for the ERI. In learning outcomes, the OOPT-M captures (a) patterns, relations, and functions, (b) problem-solving strategies, (c) numbers and number relations, (d) geometry, (e) algebra, (f) measurement, (g) estimation and mental computation, and (h) data analysis and probabilities.

Subjects

Used in this study were the OOPT-M results of 4830 fifth-graders from a large urban area in North-East Ohio. By racial groups, there were 994 White students (477 females and 517 males), 3242 Black-students (1684 females and 1558 males), 348 Hispanic students (159 males and 189 females), 38 Asian students (17 females and 21 males), and 208 students with no race and/or gender group information. The OOPT-M scores of all 4830 students were used when determining the set of ability scores. Because of the small number of Asian students, only three racial groups, White, Black, and Hispanic, were included in analyses involving the factor Race.

Procedures

For the purpose of providing IRT parameter estimates of the SRI and ERI of the test, the Generalized Partial Credit Model (Muraki, 1992) was used with calculations conducted via the computer program PARSCALE (Muraki & Bock, 1996).The Generalized Partial Credit Model (GPCM) belongs to the Rasch family of polytomous item response models. It is an extension of the partial credit model (PCM), developed by Master (1982), which is appropriate for the analysis of items that have more than two successively ordered option categories. The PCM does not contain a discriminating power parameter, while the GPCM (Muraki, 1992) does. The GPCM is based on the assumption that the probability of selecting the kth category of item j over the preceding category, k - 1, is given by the following conditional probability C_{jk} :

$$C_{jk} = \frac{P_{jk}(\theta)}{P_{j,k-1}(\theta) + P_{jk}(\theta)} = \frac{\exp[a_j(\theta - b_{jk})]}{1 + \exp[a_j(\theta - b_{jk})]}, \quad (1)$$

where $P_{jk}(\theta)$ is the probability for a person with ability θ to select the kth category from m_j possible categories of item j; ($k = 2, 3, ..., m_j$).

After solving for the $P_{jk}(\theta)$ from (1), developed for each $k = 2, 3, ..., m_j$, the result is the GPCM:

$$P_{jk}(\theta) = \frac{\exp[\sum_{t=1}^{k} a_j(\theta - b_{jt})]}{\sum_{c=1}^{m_j} \exp[\sum_{t=1}^{c} a_j(\theta - b_{jt})]} \quad (2)$$

The parameters b_{jk} in equation (2) are called *item step parameters* (ISPs). They are not sequentially ordered within item j because b_{jk} represents the relative magnitude of the adjacent probabilities $P_{j,k-1}(\theta)$ and $P_{jk}(\theta)$. Geometrically, the b_{jk} are the points on the ability scale, θ, at which the curves of $P_{j,k-1}(\theta)$ and $P_{jk}(\theta)$ intersect. These two curves, referred to as *item category*

response functions (ICRFs), intersect only once, anywhere along the θ scale.

The ability scores of the students were calculated using PARSCALE. Students with ability scores in the lower 27% were assigned to the *low ability* group, students with ability scores in the upper 27% were assigned to the *high ability* group, and the rest of the students were assigned to the *medium ability* group. The OOPT-M results were furhter analyzed by gender (male, female), race (White, Black, Hispanic), ability (low, medium, high), and type of item response (multiple-choice, short response, extended response). All statistical procedures were performed using SPSS (SPSS Inc., 1997).

Results

Table 1 shows GPCM results for the 10 items of the type SRI and ERI. The item numbers are the same as in the OOGPT-M. As the location of each item represents its difficulty, one can see, for example, that Item 34 is the most difficult item and Item 4, the easiest item among the 10 items. The discriminating power of the items, given by their slopes, varied within a relatively small interval, (.36, .79). For example, Item 19 has the highest slope, .79, and, hence, it is the best in discriminating students with different scores on the ability scale. For the interpretation of the item step information given in Table 1, it should be noted that each "step" in a given item is defined here by the partial credit score students may obtain on this item. The PC column in Table 1 shows the percent of students assigned to different scoring categories of each item. With Item 4, for example, 42.1% of the students were given a score of 0, 28.8%, a score of 1, and 29.1%, a score of 2. The ISP column shows the *item step parameter* and the SE column shows the standard error of this parameter. Still with Item 4, the ISP of .12 for the score of 1, and the ISP of -.12 for the score of 2, show that it has been more difficult for the students to make the transition from step 0 to step 1 than the transition from step 1 to step 2. With Item 11,

however, the most difficult part for the students was to make the transition from step 1 to step 2 since the highest ISP, 1.39, in this item corresponds to a score of 2.

The results from PARSCALE (Muraki &Bock, 1996) showed that the ability scores of all 4830 fifth-graders on the OOPT-M were spread between -4.82 and 3.68 on the logit scale. Students with ability scores below the 27th percentile (P_{27} = -.70) were assigned to the low ability group, students with ability scores above the 73rd percentile (P_{73} = .37) were assigned to the high ability group, and the rest of the students were assigned to the medium ability group. Table 2 shows the distribution of White, Black, and Hispanic students by gender and ability level. In proportional representation, Hispanic females were highest at the low ability level, 31%, Black males were highest at the medium ability level, 48%, and White males were highest at the high ability level, 41%. Table 3 shows the means and standard deviations of the OOPT-M scores by gender and race across the types of item response. Table 4 shows the multivariate test results for the OOPT-M score differences by gender, race, and ability. There was a significant main effect of factor Ability, which is logical, a significant main effect of factor Race, and a significant interaction between Race and Ability. There was no significant main effect of factor Gender and no significant interactions between Gender and either of the other two factors. These results show that factor Gender does not play any significant role in the OOPT-M scores of the fifth-graders.

Tables 5, 6, and 7 show the results from a multivariate repeated measures design, with one within-subjects factor, Type of item response, and one between-subjects factor, Race. The three levels of the within-subjects factor were the average z-scores of the students on the MCI, SRI, and ERI, respectively. The rationale for using these scores as repeated measures is that, in the OOPT-M, they represent three different measures of the same mathematics ability. In cases with a significant main effect of factor Race, post-hoc comparisons were conducted using the

Dunett's T3 pairwise comparisons test (see, e.g., SPSS Inc., 1997, p. 37). The results are presented by ability levels:

1. *At low ability level* (Table 5), Race was a significant factor for the OOPT-M score on the extended response items. The post-hoc comparisons (Table 8) showed a significant difference between the White and Hispanic groups, with higher performance of the Hispanic students. No significant differences between the three racial groups were found on the multiple-choice and short response items. The significance of the factor Type of item response on the within-subjects contrast (MCI - SRI) and the graphical representation in Figure 1 indicate that the performance of the low ability students increased significantly from multiple-choice to short response items. There was no significant change in the average score from short response to extended response items. Also, there was no significant interaction between Race and Type of item response. The OOPT-M profile of the low ability students, by racial groups and types of item response, is presented in Figure 1.

2. *At medium ability level* (Table 6), Race was a significant factor for the OOPT-M scores on multiple-choice items. The post-hoc comparisons (Table 8) showed a significant difference between the White and Black groups and, also, between the White and Hispanic groups. The examination of the 95% confidence intervals shows that the White students performed significantly better than both Black and Hispanic students on the multiple-choice items. There were no significant differences between the racial groups on the short response and extended response items. The factor Type of item response was found to be significant on the within-subjects contrasts (MCI - SRI) and (SRI - ERI). This results, with the interpretation of the score profiles in Figure 2, indicate that the average score of the medium ability students significantly decreased from multiple-choice to short response items and significantly increased from short

response to extended response items. The significant interaction between Race and Type of item response on the within-subjects contrast (SRI - ERI) indicates that the difference between the average scores on short response and extended response items varied significantly, in a disordinal way (see Figure 2), across the three racial groups.

3. *At high ability level* (Table 7), Race was a significant factor for the multiple-choice and extended response items. The post-hoc comparisons (Table 8) showed that the White students performed better than both Black and Hispanic students on the multiple-choice items and better than the Black students on the extended response items. There were no differences between the racial groups on the short response items. The significant interaction between Race and Type of item response on the within-subjects contrast (MCI - SRI) indicates that the difference between the average scores on multiple-choice and short response items varied significantly across the racial groups, with a disordinal trend between the Hispanic and Black groups (see Figure 3).

Discussion

The results of this study indicate that Gender did not play a significant role in the OOPT-M scores for the target population of fifth-graders. In regard to factor Race, there were significant differences in the OOPT-M performance of White, Black, and Hispanic students, but they were not in favor of a single racial group across different ability levels and types of item response.

At **low ability level**, the Hispanic students performed better than the White students on the extended response items. No other performance differences between the racial groups were found across the three types of items. The lowest performance of the low ability students from all racial groups was on the multiple-choice items (see Figure 1).

At **medium ability level**, the White students performed better than both Black and Hispanic students on the multiple-choice items. There were no other differences between the

racial groups across the three types of item response. The performance of all racial groups decreased from multiple-choice to short response items and increased from short response to extended response items. The difference between students' performance on short response and extended response items varied in a disordinal way across the racial groups (see Figure 2).

At **high ability level**, the White students performed better than both Black and Hispanic students on the multiple-choice items and better than the Black students on the extended response items. There were no other performance differences between the racial groups across the three types of item response. The performance of the students from all racial groups increased from multiple-choice to short response items and decreased from short response to extended response items. The performance difference between Black and Hispanic students varied in a disordinal way in the transition from multiple-choice to short response items (see Figure 3).

Overall, the White students performed best on the multiple-choice items, at medium and high ability levels, and on the extended response items at high ability level. The Hispanic students performed best on the extended response items at low ability level. At each ability level, there were no differences between the racial groups on the short response items. This findings suggest that structuring mathematics lessons in ways that relate to the students' culture and problem solving experience can promote the academic achievement of students of different color.

In conclusion, the results from this study provide information about the psychometric characteristics of short response and extended response items of the OOPT-M and information about the role gender and race in the performance of students with different ability levels on multiple-choice, short response, and extended response items. This information can be useful to Ohio's test analysts and educators in adapting strategies for teaching mathematics and OOPT-M training sessions to a diverse body of students in urban schools populated by minority children.

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Table 1
Parameter Estimates and Descriptive Statistics of Steps in the Short Response Items and Extended Response Items of the Ohio Off-Grade Proficiency Test-Mathematics

Item	Location[a]	Slope[b]	Step	PC[c]	Mean	S.D.	ISP[d]	SE
			0	42.1	12.64	2.49	.00	.00
4	**.29** (.02)	**.56** (.02)	1	28.8	15.10	3.28	. 12	.04
			2	29.1	18.77	4.12	-.12	.04
			0	88.5	14.45	3.50	.00	.00
8	**1.97** (.04)	**.68** (.02)	1	5.3	19.08	4.10	-.81	.06
			2	5.2	22.81	4.25	.81	.08
			0	34.5	11.99	1.98	.00	.00
			1	16.2	13.76	2.51	-.13	.07
11	**.68** (.02)	**.36** (.01)	2	25.4	16.32	3.27	1.39	.07
			3	13.0	18.24	3.27	-.83	.08
			4	10.9	20.65	3.93	-.43	.09
			0	71.0	13.74	3.10	.00	.00
15	**1.33** (.04)	**.57** (.02)	1	16.7	16.88	3.89	-.25	.04
			2	12.3	20.74	4.04	.25	.06
			0	80.8	13.97	3.17	.00	.00
19	**1.47** (.03)	**.79** (.02)	1	10.4	18.39	3.54	-.30	.04
			2	8.8	21.85	4.09	.30	.05
			0	67.6	13.35	2.67	.00	.00
24	**.95** (.02)	**.75** (.02)	1	15.3	17.14	3.60	-.26	.03
			2	17.2	20.33	4.11	.26	.04
			0	85.9	14.39	3.56	.00	.00
28	**2.32** (.07)	**.59** (.02)	1	11.0	19.24	4.49	-.02	.05
			2	3.2	21.08	4.17	.02	.09
			0	50.9	13.45	3.10	.00	.00
			1	37.9	15.54	3.32	1.71	.05
31	**2.05** (.04)	**.40** (.01)	2	4.5	19.20	4.02	-1.49	.11
			3	5.5	22.46	4.01	1.42	.13
			4	1.1	24.53	4.04	-1.63	.22
			0	93.5	14.75	3.78	.00	.00
34	**2.65** (.08)	**.70** (.03)	1	5.0	19.33	4.61	-.25	.06
			2	1.4	25.17	4.08	.25	.12
			0	56.4	13.53	3.18	.00	.00
38	**1.75** (.04)	**.51** (.02)	1	38.4	16.68	3.97	1.29	.04
			2	5.2	21.11	4.68	-1.29	.08

[a] Given in parentheses is the standard error (SE) of the location (difficulty) of the item;
[b] Given in parentheses is the standard error (SE) of the slope of the item;
[c] Percent Correct;
[d] Item Step Parameters

Table 2

Proportional Distribution of the Students Across Ability Levels by Gender and Race

	Race					
	White		Black		Hispanic	
Ability Level	Female (n = 477)	Male (n = 517)	Female (n = 1684)	Male (n = 1558)	Female (n = 159)	Male (n = 189)
Low	18	15	30	30	31	28
Medium	44	44	47	48	43	45
High	38	41	24	22	26	27

Note. The values in the table represent percentages.

Table 3

Means and Standard Deviations of OOPT-M Scores by Gender, Race, and Type of Item Response

	Race					
	White		Black		Hispanic	
Items	Female (n = 477)	Male (n = 517)	Female (n = 1684)	Male (n = 1558)	Female (n = 159)	Male (n = 189)
Multiple-Choice						
M	16.79	17.60	15.24	15.20	14.84	15.26
SD	4.55	4.67	4.30	4.27	4.30	4.42
Short Response						
M	3.47	3.91	2.80	2.57	2.84	2.98
SD	2.97	3.20	2.75	2.60	2.94	2.94
Extended Response						
M	2.48	2.76	2.05	2.01	2.31	2.28
SD	1.92	2.06	1.67	1.75	1.80	1.85

Note. The maximum possible score is 31 for the multiple-choice, 16 for the short response, and 8 for the extended response items.

Table 4

Multivariate Tests of OOPT-M Score Differences by Gender, Race, and Ability Level

Source	Wilks' lambda	df[a]	df[b]	F
Gender (G)	.99	3	4564	1.71
Race (R)	.99	6	9128	6.17**
Ability (A)	.34	6	9128	1088.42**
G x R	.99	6	9128	1.33
G x A	.99	6	9128	0.80
R x A	.99	12	12075	3.10**
G x R x A	.99	12	13688	0.90

[a] Hypothesis degrees of freedom. [b] Error degrees of freedom.

*$p < .05$. **$p < .01$.

Table 5

Multivariate Repeated Measures Analysis on OOPT-M Scores for Students at Low Ability Level

Source	df	F		
		MCI	SRI	ERI
		Between subjects		
Race (R)	2	1.86	.79	3.06*
Error	1231	(0.30)	(0.06)	(0.18)
		Within subjects contrasts		
		MCI - SRI	SRI - ERI	
Type (T)[a]	1	45.03**	0.16	
T x R	2	2.50	1.36	
Error	1234	(0.37)	(0.27)	

Note. Values enclosed in parentheses represent mean square errors. MCI - SRI is the difference between multiple-choice and short response items, and SRI - ERI, between short response and extended response items.

[a] Type of item response.

*$p < .05$. ** $p < .01$.

Table 6

Multivariate Repeated Measures Analysis on OOPT-M Scores for Students at Medium Ability Level

		F		
Source	df	MCI	SRI	ERI
		Between subjects		
Race (R)	2	7.33**	2.76	1.99
Error	1648	(0.38)	(0.23)	(0.53)
		Within subjects contrasts		
		MCI - SRI	SRI - ERI	
Type (T)[a]	1	73.80**	35.54**	
T x R	2	1.26	3.70**	
Error	2118	(0.62)	(0.87)	

Note. Values enclosed in parentheses represent mean square errors. MCI - SRI is the difference between multiple-choice and short response items, and SRI - ERI, between short response and extended response items.

[a] Type of item response.

*p < .05. ** p < .01.

Table 7

Multivariate Repeated Measures Analysis on OOPT-M Scores for Students at High Ability Level

Source	df	F		
		MCI	SRI	ERI
		Between subjects		
Race (R)	2	11.91**	1.84	7.94**
Error	1231	(0.51)	(0.78)	(0.82)
		Within subjects contrasts		
		MCI - SRI	SRI - ERI	
Type (T)[a]	1	50.92**	30.71**	
T x R	2	3.93*	1.37	
Error	1234	(0.80)	(1.36)	

Note. Values enclosed in parentheses represent mean square errors. MCI - SRI is the difference between multiple-choice and short response items, and SRI - ERI, between short response and extended response items.

[a] Type of item response.

*p < .05. ** p < .01.

Table 8

Post-Hoc Comparisons for Significant Main Effects of Factor Race

Type of Item Response	Group 1	Group 2	Mean Difference [a] (Group1 - Group2)	SE	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
			Low Ability Level			
ERI	White	Hispanic	0.13*	0 .05	0.01	0.26
			Medium Ability Level			
MCI	White	Black	0.12**	0.03	0.04	0.20
MCI	White	Hispanic	0.16*	0.06	0.03	0.30
			High Ability Level			
MCI	White	Black	0.20**	0.04	0.09	0.30
MCI	White	Hispanic	0.29**	0.08	0 .08	0.50
ERI	White	Black	0.22**	0.06	0.08	0.36

Note. Reported are only significant mean differences captured by the post-hoc tests.

[a] In z-scores.

* $p < .05$. ** $p < .01$.

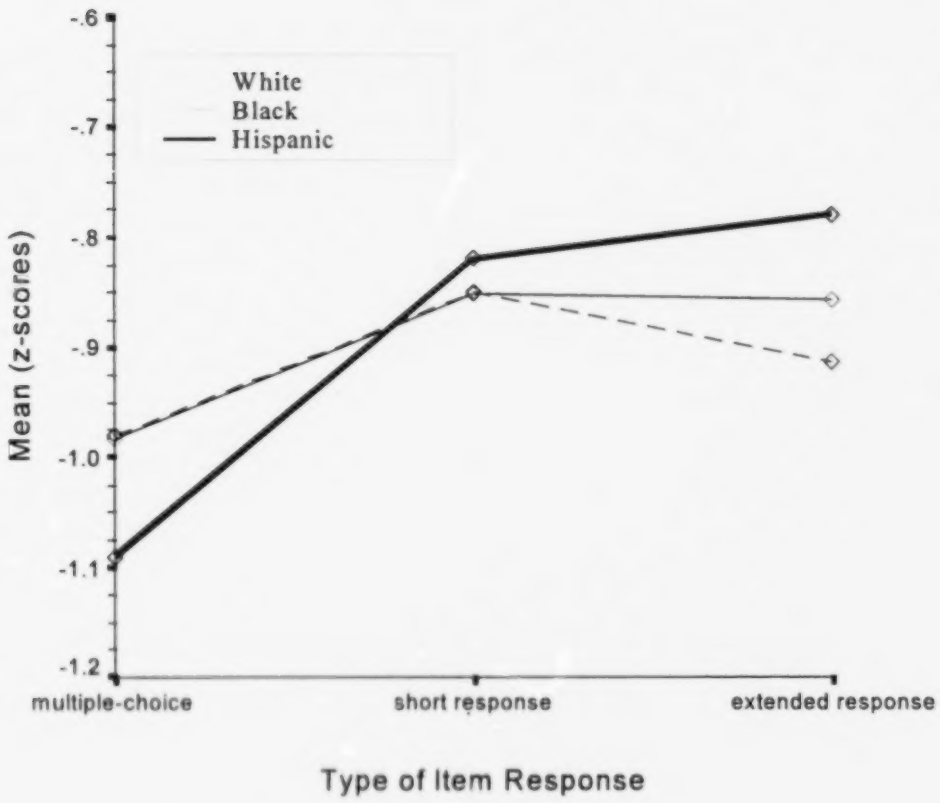

Figure 1. OOPT-M performance profiles of low ability students by racial groups

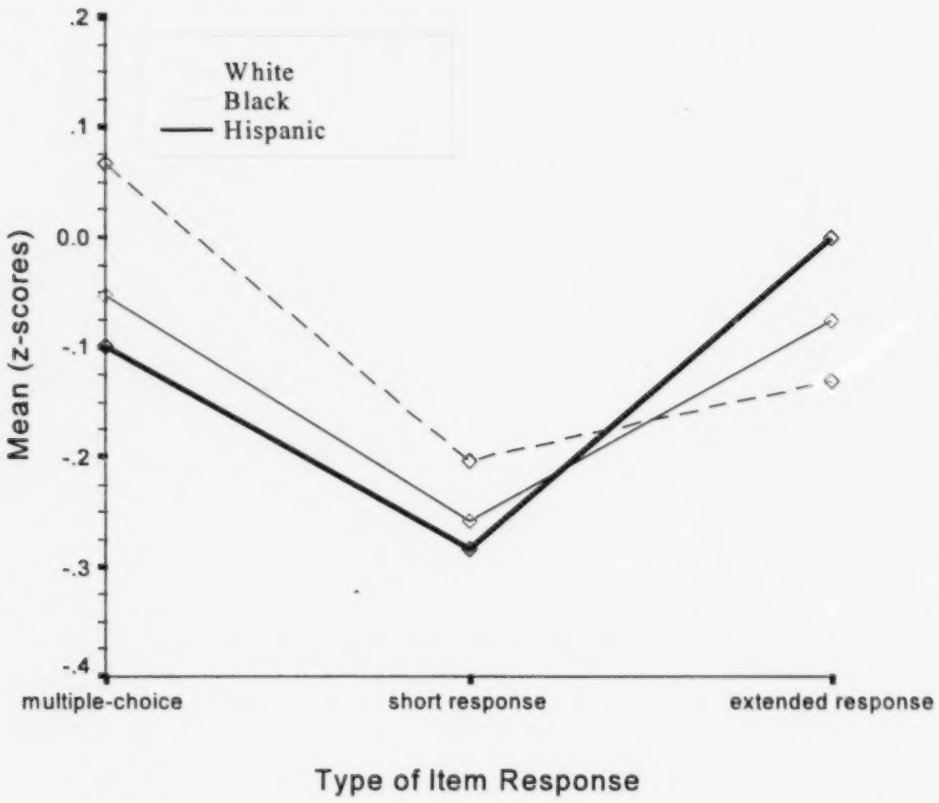

Figure 2. OOPT-M performance profiles of medium ability students by racial groups

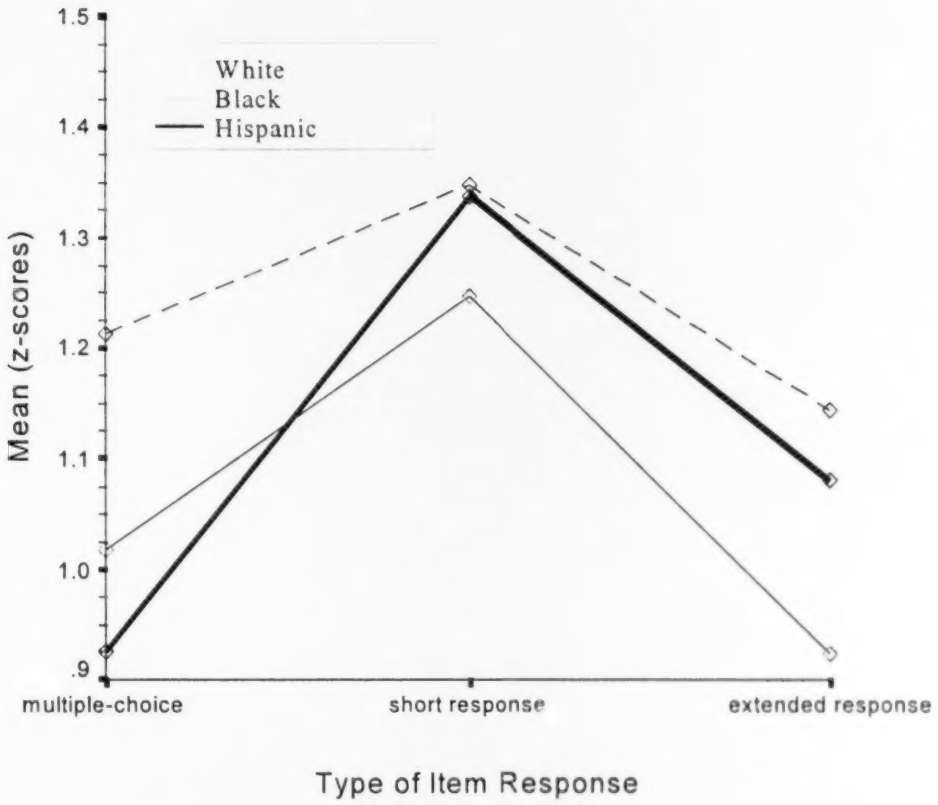

Figure 3. OOPT-M performance profiles of high ability students by racial groups